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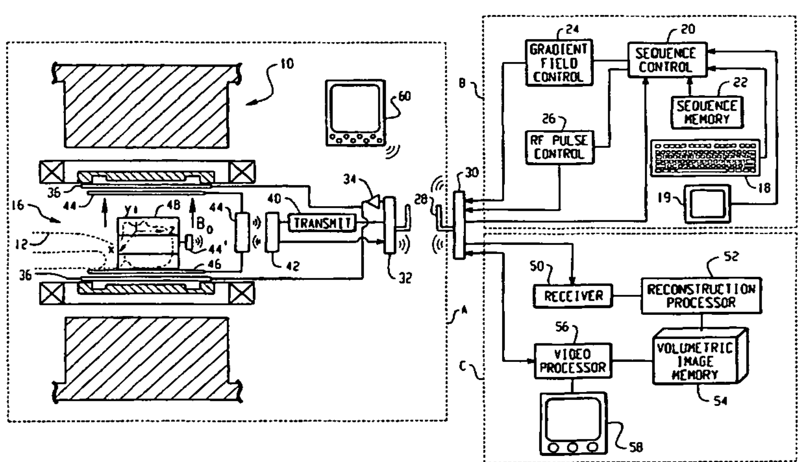
(54) Title: WIRELESS CONTROLLER AND APPLICATION INTERFACE FOR AN MRI SYSTEM



(57) Abstract: A wireless remote control unit (60) that operates in the radio frequency bandwidth is used for interfacing with a sequence control system (B) and an image processing system (C) from within a magnetic resonance suite (A) in the presence of a magnetic field produced by a main magnet assembly (10). The sequence control system and the image processing system are connected with a first wireless transceiver (30) whose antenna (28) is located within a magnetic resonance suite. The first transceiver (30) communicates with the remote control unit (60) and a second transceiver (32) connected with a transmitter (40) and gradient coil amplifiers (34). Resonance signals received by a radio frequency coil (46) are communicated to the first transceiver (30) by the second transceiver (32) or by a transceiver (46') mounted on the receiving coil. The receiver coil transceiver also engages in a handshake protocol to identify itself.

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WIRELESS CONTROLLER AND APPLICATION INTERFACE FOR AN MRI SYSTEM

Background of the Invention

The present invention relates to the diagnostic imaging arts. It has particular application in conjunction with wireless communication in a magnetic resonance setting and will be described with particular reference thereto. It will be appreciated, however, that the invention is also applicable to other modalities including, but not limited to, CT, SPECT, and PET.

Magnetic resonance (MR) imagers generate high magnetic fields through an imaging region. A typical by-product of the production of this field is a magnetic fringe field that can extend several meters beyond the physical apparatus. Although the excitation fields are high, the induced resonance signals are weak comparable with ambient television and radio signals. In order to minimize disruption to and interference from the surroundings in an environment such as a hospital or clinic, the magnets are often built within specially shielded suites to prevent the fringe field from affecting surrounding objects or people.

As a result, control hardware components for an MR apparatus are placed outside the shielded room. When controlling the apparatus and recalling images, the operator is outside the suite at the control station. This typically leaves the patient unattended during the scan. In many patients, being alone and in such a constricted area such as the bore of an MR device can cause increased anxiety and restlessness, ultimately degrading image quality.

Typically, power and control cables are fed into the MR imaging suite. Cables typically present a problem in that they can introduce radio frequency (RF) disturbances into the imaging volume and receive ambient RF signals. Ultimately, these RF disturbances manifest as imaging artifacts in final images. Typically, these cables are heavily shielded to prevent interference with radio frequency fields produced by

the MR device, and vice versa, to prevent the RF fields from corrupting information fed through the cables. As a result of shielding, these cables become quite bulky, and present obstacles within the MR suite. This can restrict access to the MR device from wheelchairs, gurneys, walkers, or other mobility limited patients, as well as lessen mobility of the operator, or other support staff about the device.

A further disadvantage of cables in the MR suite is that detuning of the coils is possible. RF receive coils become less sensitive to the resonance frequency, thereby decreasing the signal to noise ratio. In addition, cables can focus RF power onto small portions of the patient, posing potential health hazards.

The present invention provides a new and improved method and apparatus which overcomes the above-referenced problems and others.

Summary of the Invention

In accordance with one aspect of the present invention, a magnetic resonance apparatus is provided. A magnet means generates a main magnetic field through a subject in an imaging region. A sequence control means generates magnetic resonance sequences. An RF means receives resonance signals from the imaging region. An image processing means processes the resonance signals into images. A wireless interface means provides wireless communication between systems of the magnetic resonance apparatus.

In accordance with another aspect of the present invention, a method of magnetic resonance is provided. A main magnetic field is induced through a subject in an imaging region. Magnetic resonance is excited and manipulated. Requests to a control console are made with radio frequency signals. Resonance signals are received, demodulated, and reconstructed into an image representation of the subject in the imaging region.

One advantage of the present invention resides in improved mobility for patients and operators around an MR device.

Another advantage resides in the ability of the operator to remain close to the patient during the scan.

Another advantage resides in the reduction of cumbersome material within the medical imaging suite.

Another advantage resides in the ability of the operator to control the MR device from locations other than the control console.

Still further benefits and advantages of the present invention will become apparent to those skilled in the art upon a reading and understanding of the preferred embodiments.

Brief Description of the Drawings

The invention may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for purposes of illustrating preferred embodiments and are not to be construed as limiting the invention.

FIGURE 1 is a diagrammatic illustration of wireless communication in an MR environment, in accordance with the present invention;

FIGURE 2 is a diagrammatic illustration of a hand held remote interface unit, in accordance with the present invention.

Detailed Description of the Preferred Embodiment

With reference to FIGURE 1, an open main magnet assembly **10** which generates a temporally constant main magnetic field, typically denoted $\mathbf{B}_o$, vertically through an imaging region **16** is disposed in a magnetic resonance suite **A**. It should be noted that although depicted in conjunction with an open magnet system, the preferred embodiment of the present invention is equally applicable to bore type systems. A subject **12** is disposed on a patient support located in the

imaging region **16** of the magnet assembly **10**. The main magnet assembly, **10** is located within a magnetic resonance suite, which is preferably shielded to be impervious to electromagnetic radiation, particularly in the radio frequency band.

A sequence control system **B** generates magnetic resonance imaging sequences. A keyboard **18** or touch screen **19** receives operator control commands. A sequence control processor **20** withdraws a selected magnetic resonance sequence from a sequence memory **22**. A gradient field controller **24** produces gradient waveforms in accordance with the selected sequence. Concurrently, an RF pulse controller **26** generates RF pulse patterns in accordance with the selected sequence.

At least an antennae **28** of a first wireless interface, such as a transceiver **30**, is located within the imaging suite **A**. The wireless interface **30** encodes (preferably digitally)and transmits the gradient waveforms and the RF pulse patterns on a high frequency carrier wave to a second transceiver **32**. The second transceiver decodes the gradient pulse waveforms and communicates them to RF shielded gradient amplifiers **34** which are connected with gradient coils **36**. The gradient coils **36** impose gradient fields along the main magnetic field $\mathbf{B}_o$ thereby spatially encoding the main magnetic field. The second transceiver also decodes the RF pulse pattern information and supplies RF pulse information to an RF shielded transmitter **40**. In one embodiment, the transmitter is connected directly with the RF coil. In the illustrated embodiment, the transmitter is connected to a third transceiver **42** which is in radio communication with a fourth transceiver **44** on an RF coil **46**. The RF coil **46** includes a coil identification. A handshaking protocol between transceivers **42** and **44** identifies the coil to the rest of the system. In a system with multiple local or other receive coils, each receive

coil has an identification so the system can identify each coil with a handshaking protocol. The third and fourth RF transceivers **42, 44** share a similar relationship to the first and second RF transceivers **30, 32** as discussed previously. The RF coil **46** transmits the RF pulses into the imaging region **16,** exciting and manipulating magnetic resonance in accordance with the selected sequence. The RF receive coil receives the resultant resonance signals which are transmitted to the wireless interface **30** directly or via the second and third transceivers **32, 42.** Preferably, the scanner includes the whole body RF coil **46** and a plurality of localized coils, such as head coil **48.** The RF coils each include a unique identifier and a transceiver **44'.** The transceivers **42** and **44, 44'** are preprogrammed with a handshake protocol by which the transceiver **42** interrogates the transceiver **44, 44'** to and receives an identification of the coil. The coil information is communicated to the sequence control system to verify that the correct coil is installed and to make any sequence adjustments to customize the sequence to the specific RF coil.

In the preferred embodiment, the antenna **28** of first transceiver **30** is mounted to an inside wall of the magnetic resonance suite **A.** Cables connecting the first transceiver **30** to the antenna **28** are fed through the wall. The second transceiver **32** is preferably mounted adjacent the magnet assembly, with as little cable as possible connecting it to the gradient amplifier **34,** the transmitter **42** (in the direct wire embodiment), and other systems of the MR apparatus. Preferably, the first and second transceivers **30, 32** have a line of sight with each other free from any radio-opaque materials in the magnetic resonance suite.

In the preferred embodiment, the first and second transceivers **30, 32** transmit in a higher frequency band than the RF coil **44.** In a 1.5 T magnet, hydrogen dipoles (most commonly used for imaging) precess at approximately 64 MHZ; in

a 0.75 T magnet, the resonance frequency is approximately 32 MHZ. In order to tip these dipoles into the transverse plane, as is common practice, RF pulses containing frequency components close to this precession frequency are synthesized by the RF pulse controller **26**. In the preferred embodiment, the transceivers **30, 32, 42, 44** transmit carrier waves of approximately 2.4 GHz. This ensures that RF signals from the transceivers do not interfere with RF signals used for imaging. Although about 2.4 GHz is the preferred frequency range, any frequency above about 500 MHZ is acceptable. Frequencies below 500 MHZ can begin to interfere with the RF signals used for excitation and manipulation, especially in higher field systems where the dipoles precess with higher frequencies.

Signals from resonating dipoles are detected by the RF coil **46** or dedicated receive coils **48** and preamplified. The detected resonance signals are encoded and transmitted by the patient side transceiver **44** either to the transceiver **42** or directly to the transceiver **30**. The first transceiver **30** receives and decodes the resonance signals and sends the resonance signals to an image processing system **C**. A receiver **50** preferably digital, demodulates the resonance signals. The demodulated resonance signals are reconstructed into an image representation of the subject **12** in the imaging region **16** by a reconstruction processor **52**. The images are stored in a volumetric image memory **54**, where they remain until needed. A video processor **56** extracts portions needed for viewing, which portions are displayed on a human readable display **58** such as a video monitor, LCD display, active matrix monitor, or the like.

With reference to FIGURE 2 and continuing reference to FIGURE 1, the preferred embodiment of the invention includes a hand-held remote control interface unit **60**. The remote control unit **60** allows the operator to communicate with the sequence control system and the image processor system of the MR apparatus. In the preferred embodiment, the remote unit **60**

includes a display **62**. From the display **62**, the operator is able to observe information regarding the current scan. Such information includes, but is not limited to, elapsed scan time, estimated remaining scan time, selected portions of reconstructed images, available options, etc. Such devices as palm pilots, laptop computers, and the like are contemplated as available embodiments. Cellular phone units are also contemplated.

The remote unit also includes a user input portion **64**. This portion allows the operator to relay instructions to the sequence control and image processing systems. Instructions contemplated can be as simple as ordering the commencement or abortion of an imaging sequence, and more complex, such as selecting sequences, adjusting RF pulse bandwidth, or changing the size of the k-space data matrix. Instructions can also be sent to the scanner to start or stop a sequence, adjust patient position, select among receive or transmit coils, establish voice communication with the patient, and the like. The input portion **64** may include a touch screen, keyboard, voice recognition, mouse, or any combination thereof. The input portion **64**, of course, is not limited to these devices.

The remote unit **60** includes a transmitter **66** and a receiver **68** that facilitate communication. These two portions are connected to an antenna similar to those found in cellular phones. The 2.4 GHz frequency band does not interfere with the RF pulses which excite and manipulate magnetic resonance or the resultant resonance signals. Moreover, when the device is operated within the shielded suite, it does not interfere with cellular communications in the area. An exemplary realization of such a transceiver is embodied in the Bluetooth™ technology by Ericsson mobile phones.

Also included in the remote unit **60** is a microprocessor **70**. The microprocessor **70** processes input from the operator and information transmitted by the first

transceiver **30** for display on the remote unit **60**. Optionally, the microprocessor **70** is included elsewhere, remote from the hand-held unit **60**.

The remote unit **60** includes a power source. The power source is selected according to the power consumption needs of the remote unit **60**. Typical power sources include batteries (disposable or rechargeable), storage capacitors which are charged by AC power or power from RF pulses, and solar cells.

In another application of the preferred embodiment, the remote unit **60** is also used in conjunction with peripherals not immediately associated with the MR apparatus. Such devices include ECG machines, respirators, and the like. Communication between the remote unit and the peripheral devices allow the operator to see patient blood pressure, heart rate, and other variables on the remote unit **60**. Preferably, each peripheral device has at least a transmitter that transmits directly to the remote unit **60**. Optionally, if the microprocessor **70** is not located in the hand held unit **60**, then the peripheral device transmits to the first transceiver to process the information transmitted before transmission to the remote unit **60**.

In an alternate embodiment, the remote unit is used outside of the imaging suite. In this embodiment, The suite would not be shielded against high frequency RF signals in order to let information to pass into the room.

In another alternate embodiment, the remote unit **60** and transceivers **30, 32, 42, 44, 44'** transmit in the infrared spectrum, rather than the radio frequency spectrum.

In another alternate embodiment, the remote unit **60** is used in conjunction with a CT or nuclear imaging scanner. In this embodiment, a greater range of radio frequencies are available, as there are no RF imaging pulses with which to interfere.

In another alternate embodiment, the remote interface lacks the input portion **64** and transmitter **66**. In this embodiment, the remote unit **60** is a receive only device that displays information as discussed above, but does not accept user input.

Having thus described the preferred embodiments, the invention is now claimed to be:

1. A magnetic resonance apparatus comprising:

a magnet means **(10)** for generating a main magnetic field through a subject **(12)** disposed in an examination region **(16)**, the magnet means **(10)** being disposed in a magnetic resonance suite;

a sequence control means **(20)** for generating magnetic resonance sequences;

an RF means **(46)** which at least receives resonance signals from the examination region **(16)**, the RF means **(46)** being disposed adjacent the examination region **(16)**;

an image processing means **(52, 56)** which processes the resonance signals received by the RF means **(46)** into images and manipulates the reconstructed images;

a wireless interface means **(30, 32)** disposed with an antennae **(28)** in the magnetic resonance suite for wireless communication between (i) at least one of the sequence control means **(20)** and the image processing means **(52, 56)** and (ii) at least one of the RF means **(46)** and a wireless remote control means **(60)** for communicating between an operator and at least one of the sequence control means **(20)** and the image processing means **(52, 56)**.

2. The magnetic resonance apparatus as set forth in claim 1, wherein the remote control means **(60)** includes:

a display means **(62)** for relaying information from at lest one of the sequence control means **(20)** and the image processing means **(56)** to the operator;

an input means **(64)** for accepting requests from the operator;

an RF transmitting means **(66)** for transmitting the operator requests to the wireless interface means.

3. The magnetic resonance apparatus as set forth in claim 2, wherein the remote control means **(60)** further includes:

a radio frequency receiving means **(68)** for receiving radio frequency signals from at least the wireless interface means.

4. The magnetic resonance apparatus as set forth in claim 3, further including:

a microprocessing means **(70)** for processing operator input to the remote control means **(60)**.

5. The magnetic resonance apparatus as set forth in one of claims 2-4, wherein the input means includes at least one of:

a keyboard;
a touch screen; and,
a voice recognition device.

6. The magnetic resonance apparatus as set forth in any one of the preceding claims, wherein the wireless interface means and the at least one of the remote control means **(60)** and the RF means **(46)** communicate with carrier frequencies greater than 500 MHZ.

7. The magnetic resonance apparatus as set forth in claim 6, wherein the carrier frequencies are between 2.3 and 2.6 GHz.

8. The magnetic resonance apparatus as set forth in any one of the preceding claims, further including:

an RF transmitting means **(40)** disposed adjacent the RF means **(46)**;

a radio frequency transceiving means **(42)** connected with the transmitting means **(40)** for communicating between the RF transmitting means **(40)** and the wireless interface means.

9. The magnetic resonance apparatus as set forth in any one of the preceding claims, further including:

additional radio frequency transceiving means **(42, 44)** for providing a wireless communication pathway between a radio frequency transmitting means **(40)** and the RF means **(46)**.

10. A method of magnetic resonance comprising:

inducing a main magnetic field through a subject **(12)** in an imaging region **(16)**;

exciting and manipulating magnetic dipoles within the imaging region to generate magnetic resonance signals;

receiving and demodulating the magnetic resonance signals;

reconstructing the demodulated resonance signals into an image representation of the patient in the imaging region **(16)**; and

wirelessly communicating at least one of exciting and manipulating instructions, the resonance signals, and image processing instructions with radio frequency signals.

11. In the magnetic resonance imaging system as set forth in claim 10 wherein the communications are digitally encoded on the radio frequency communication signals.

12. The method as set forth in one of claims 10 and 11, further including:

identifying an RF coil **(46, 48)** with which the magnetic resonance signals are received using a radio frequency communicated handshaking protocol.

13. The method as set forth in any one of claims 10-12, wherein the radio frequencies are greater than 500 MHZ.

14. The method as set forth in any one of claims 10-13, further including:

wirelessly communicating and displaying information pertinent to a current magnetic resonance scan on a remote unit **(60)**.

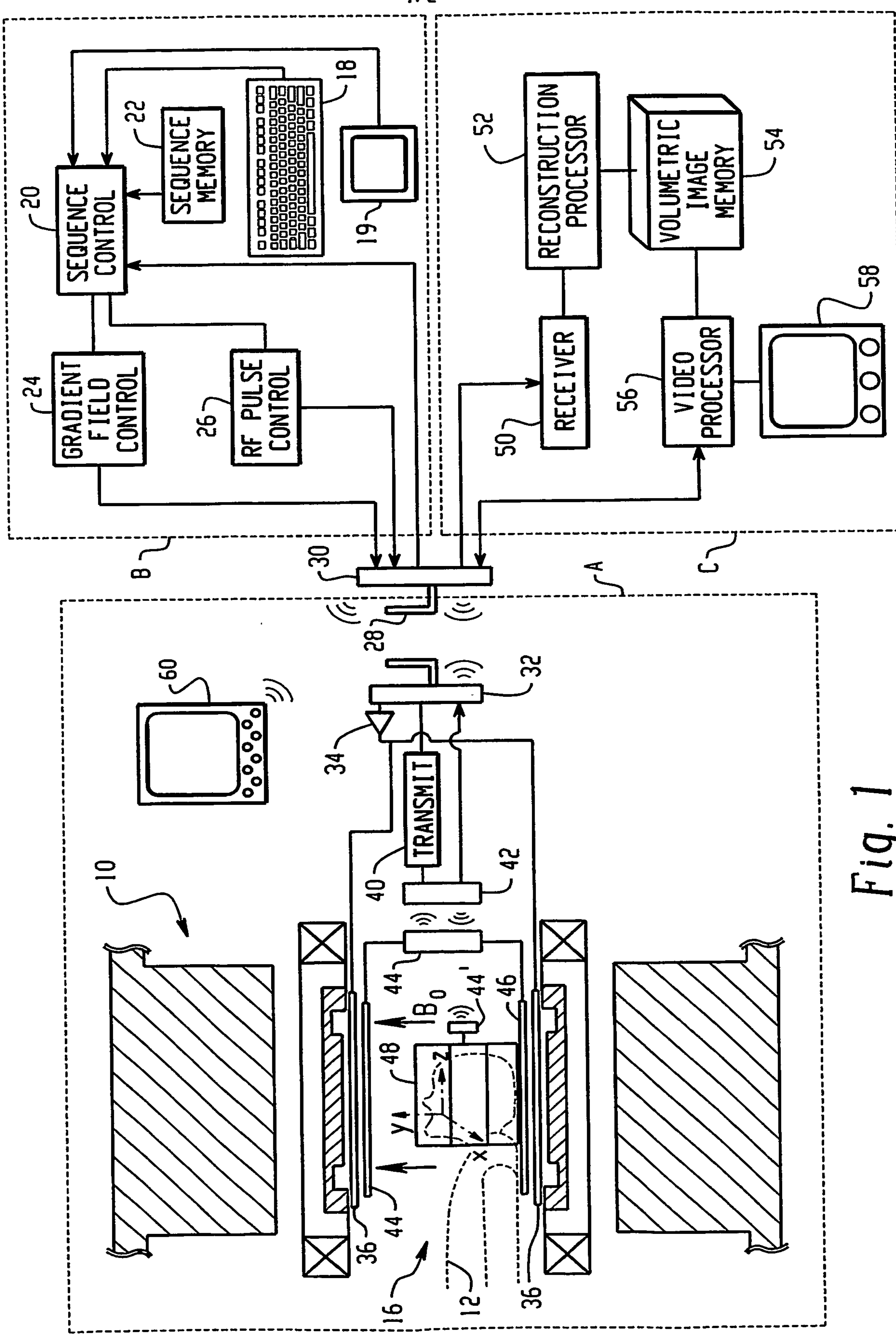
15. The method as set forth in claim 14, further including:

receiving reconstructed image information with the remote unit **(60)**;

displaying the received image information on the remote unit **(60)**.

16. The method as set forth in any one of claims 10-15, further including:

wirelessly communicating an identification of an RF receiving coil **(46, 48)** which is mounted adjacent the imaging region **(16)** to receive resonance signals emanating from the subject **(12)**.


SEQUENCE CONTROL
SEQUENCE MEMORY
GRADIENT FIELD CONTROL
RF PULSE CONTROL
RECONSTRUCTION PROCESSOR
VOLUMETRIC IMAGE MEMORY
RECEIVER
VIDEO PROCESSOR
TRANSMIT
B_0
X
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Z
A
B
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Fig. 1

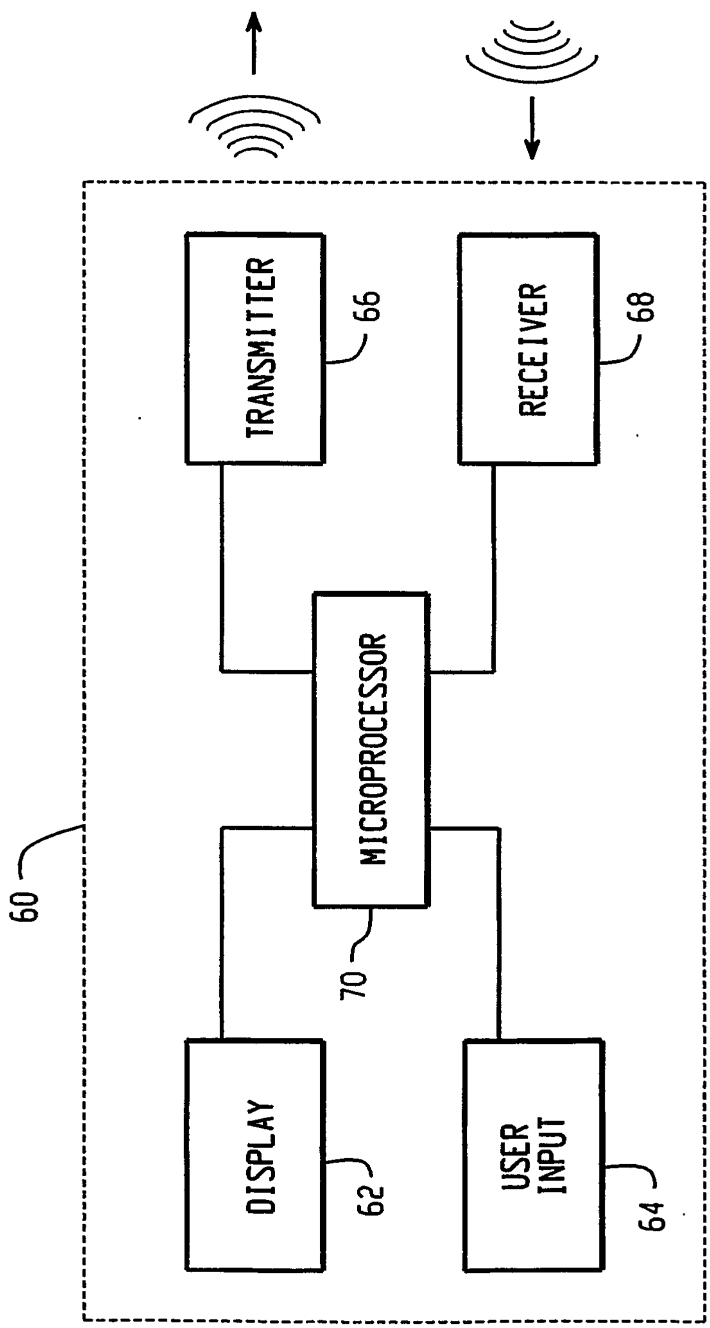
TRANSMITTER
66
RECEIVER
68
MICROPROCESSOR
70
60
DISPLAY
62
USER INPUT
64

Fig. 2

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 02/32123

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01R33/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 384 536 A (MURAKAMI YOSHIKI ET AL) 24 January 1995 (1995-01-24) column 4, line 29 -column 9, line 65; figures 2-11	1,6-13, 16
X	US 6 198 285 B1 (KORMOS DONALD W ET AL) 6 March 2001 (2001-03-06) column 1, line 40 -column 2, line 48 column 4, line 32 -column 8, line 57; figures 1,4	1-7,10, 11,13-15
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 March 2003	14/03/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Lersch, W

Form PCT/ISA/210 (second sheet) (July 1992)

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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